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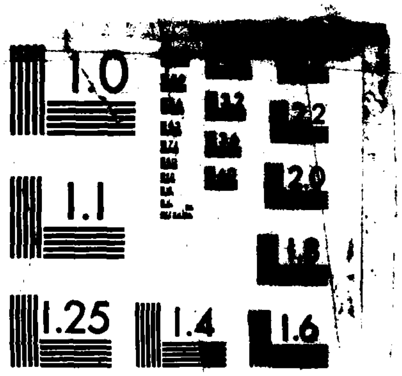

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Transcient Simulation of Submicron Devices

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Introduction

Previously the Legendre-Hermite polynomial expansion of Boltzmann's equation (1) has been used to calculate the velocity-field characteristic of InP at room temperature (2). In this report application of the method to a millimetre wave InP Gunn diode is described.

Device Simulation

An InP n^+-n-n^+ plane diode with a base width of 0.7 um and doping of $3x10^{16}/cm^3$ has been studied at an assumed operating temperature of 493 K. The exact doping profile is included in Fig. 3.
These data were chosen because a similar diode was simulated at the University of Lille by Friscourt et al. (3) using an energy relaxation method and it was thought interesting to compare both methods.
In our simulation method carrier transport was calculated by the LHE method and Poisson's equation was solved simultaneously, taking time steps of about 10^{-14} sec. The boundary conditions at the contacts were cyclical, that is, electrons leaving the device through one contact were injected with the same velocity at the other. To make sure the electrons in the anode contact layer have enough time to cool off both contact layers were taken fairly thick.
Fig. 1 shows the d.c. current-voltage characteristic. An operating point of 3 V was chosen and a sinusoidal a.c. voltage at a frequency of 143 GHz was superimposed. The resulting current waveform was

Fourier analyzed and the power output at the fundamental frequency calculated. This is shown in Fig. 2 as a function of a.c. voltage amplitude. At the point of maximum power output, 1.5 V a.c. amplitude, pictures were taken of the carrier density, field and velocity profiles at eight points in the a.c. period. These are shown in Fig. 3. Clearly the device is operating in an accumulation layer transit mode. Also it can be noted that the carrier velocity overshoots the maximum static velocity in a large portion of the device during part of the period.

Finally the behaviour of the diode in an oscillator circuit was studied. The circuit and the resulting current and voltage waveforms are shown in Fig. 4. After an initial transient caused by the abrupt turn-on of the bias voltage the circuit settles into a stable oscillation condition. It can be seen that the device current contains an appreciable second harmonic component. Also the average current is lower than in the non-oscillating condition (cf. Fig. 1) which suggest application as a self-oscillating mixer.

References

1. S.C. Van Someren Greve, Dr. Thesis, Eindhoven University of Technology Nov. 1984, ISBN 90-9000778-4.
2. First Interim Report.
3. M.R. Friscourt, P.A. Rolland, A. Cappy, E. Constant, G. Salmer, IEEE Trans ED-30, 223, 1983.

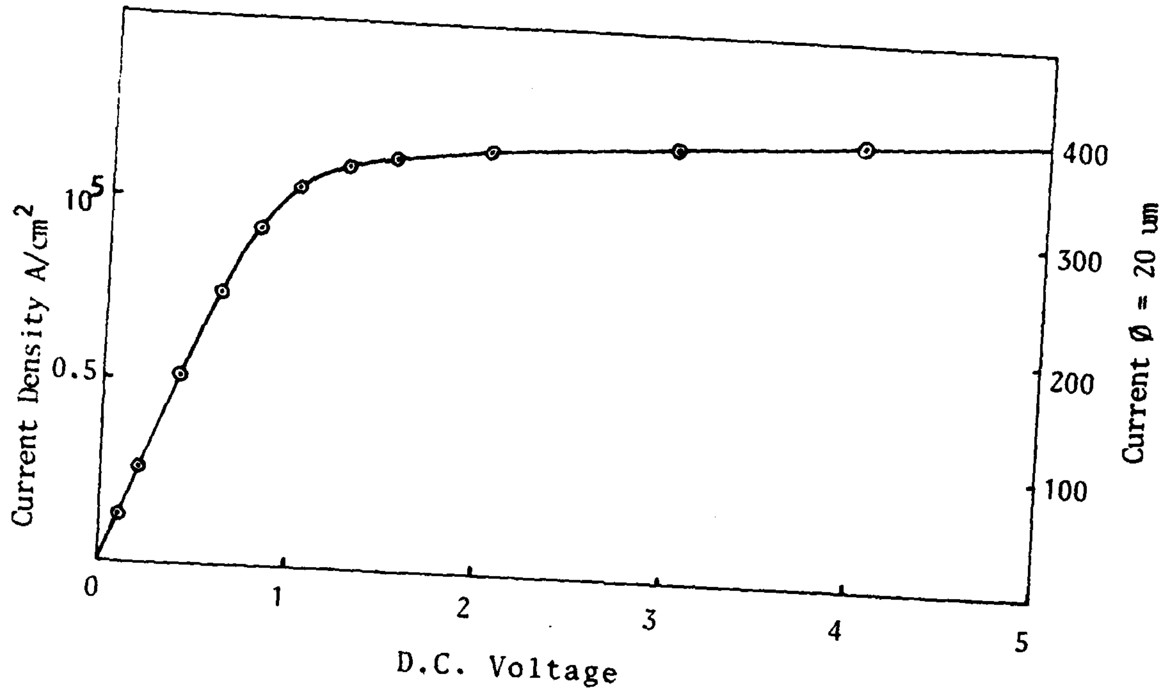

Fig. 1. Current-Voltage characteristic of an InP Gunn diode

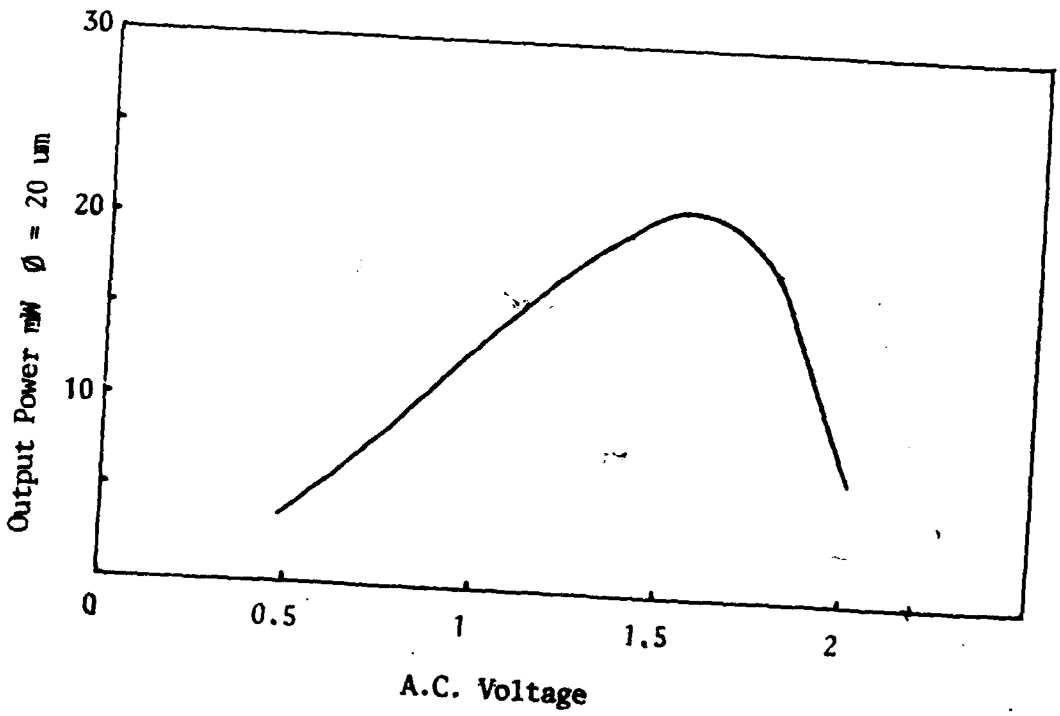

Fig. 2. Output power vs. a.c. voltage amplitude at 3 V d.c. bias.

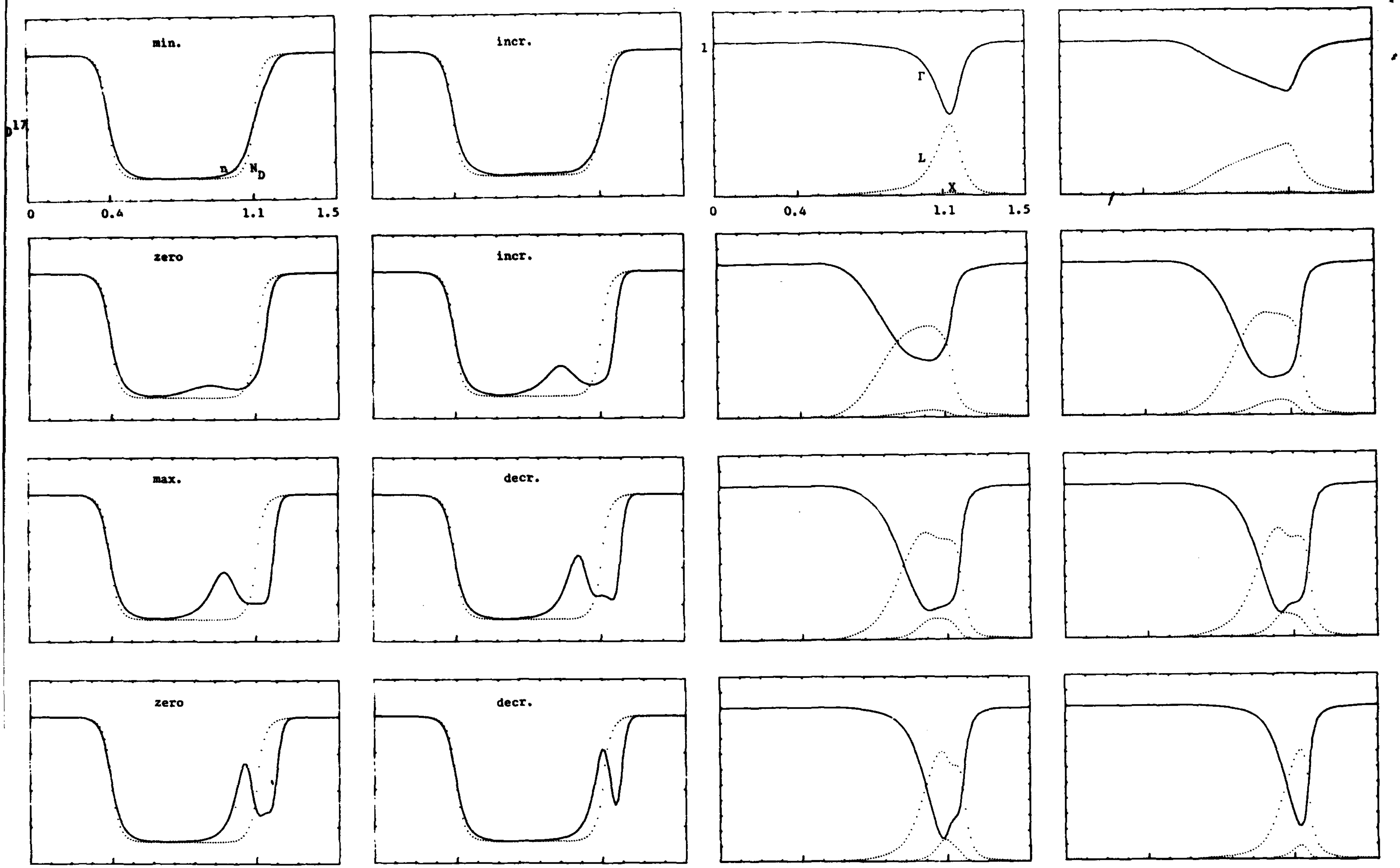

Fig. 3a. Electron density (cm^{-3}) and valley population (relative) as a function of position (in um) during an a.c. cycle. The text at the top of the pictures gives the phase of the a.c. voltage.

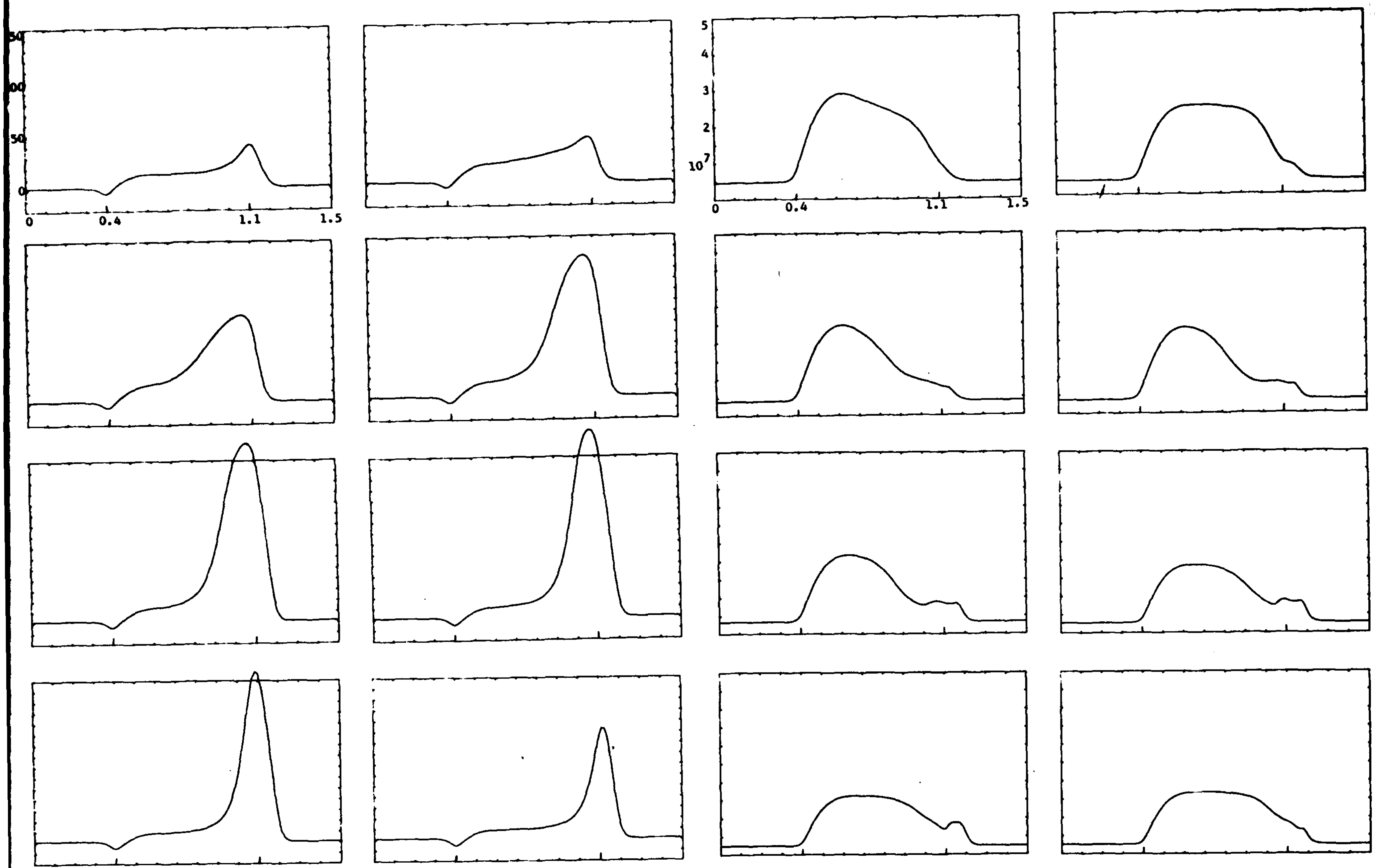

Fig. 3b. Electric field (kV/cm) and electron velocity (cm/sec).

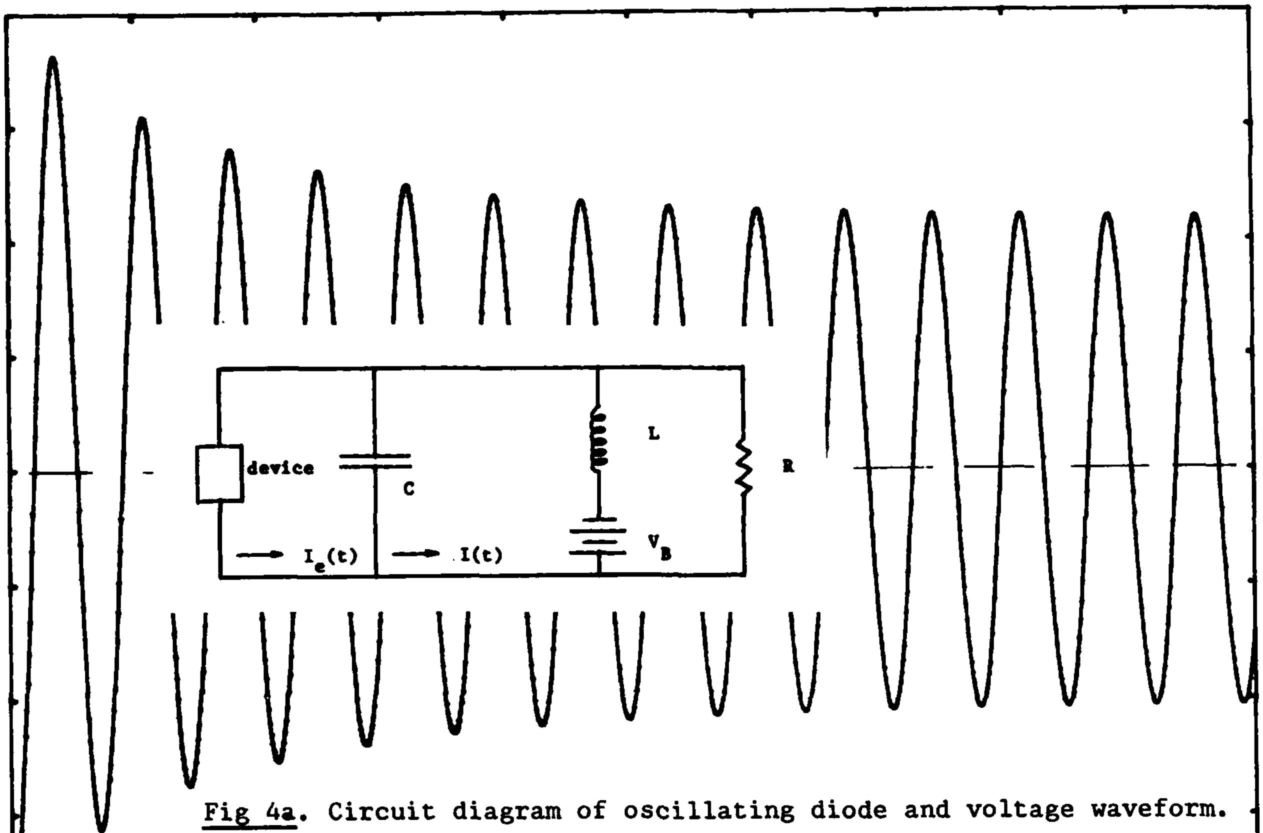

Fig 4a. Circuit diagram of oscillating diode and voltage waveform. Vertical scale 1 V/div, horizontal 10 psec/div.

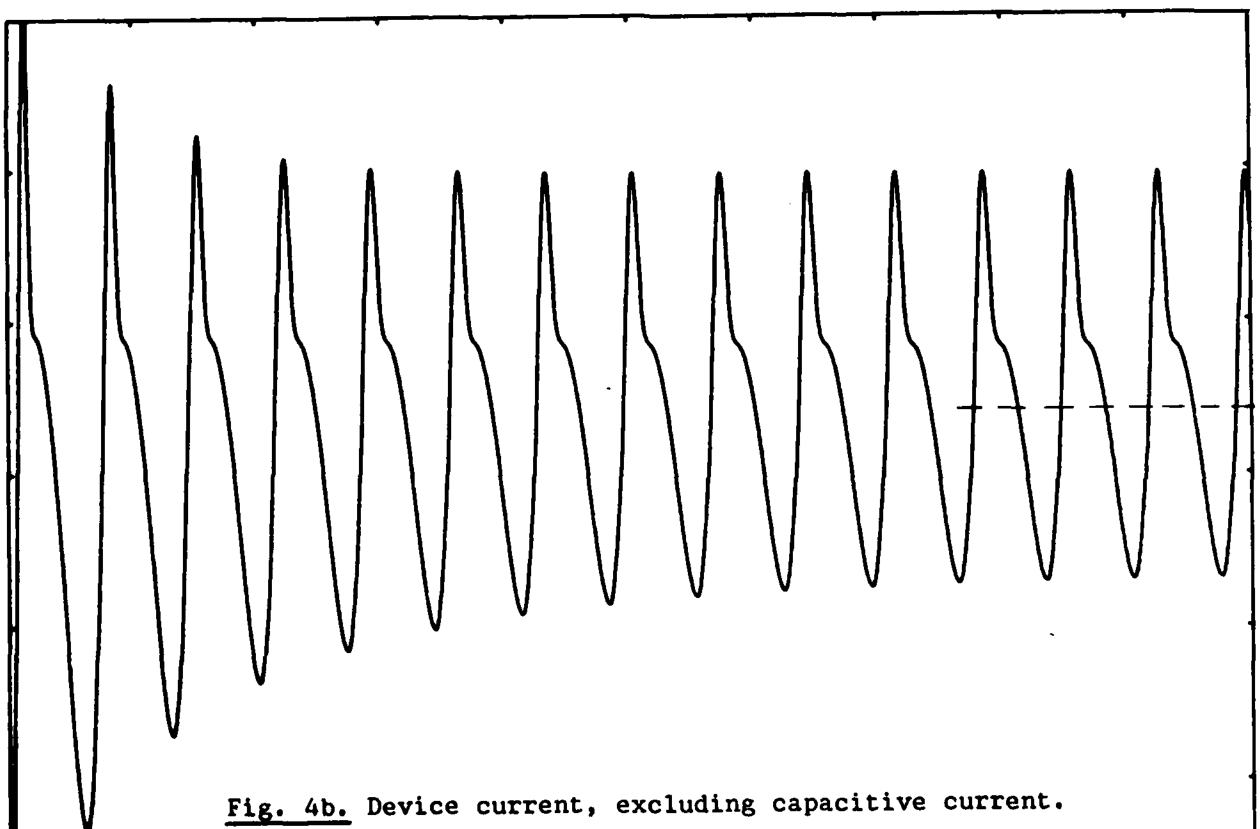

Fig. 4b. Device current, excluding capacitive current. Vertical scale 100 mA/div.

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